WATER METERING IN HOBART - AN APPRAISAL OF THE COST-BENEFIT STUDY

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This dissertation is submitted as part of the requirements for an honours degree in Economics at the University of Tasmania.

I certify that this dissertation represents my own original work, that it contains no material which has already been published or otherwise used by me, and that to the best of my knowledge it contains no copy or paraphrase of material previously written by another person or authority, except where due acknowledgement is made.

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PREFACE

Hobart is the only capital city in Australia where water is supplied to the consumers unmetered. A flat rate is charged annually in return for which consumers may take virtually unlimited water. There seems to be a prevalent belief that water should not be sold to the community of Hobart on the basis of consumption because of the natural abundance of water in Tasmania. This view is reflected in the 'requirements approach' used by the Metropolitan Water Board in planning supply expansions. What is little realised is that the source of Hobart's water (although virtually inexhaustible) is situated a fairly great distance away from the metropolitan area. Transporting water through pipelines over long distances is not a cost-less affair and by virtue of this fact, water must be looked upon and treated as an economic good.

This study has a three-fold objective. Firstly, it is to examine the efficacy of the present investment criteria used by the Metropolitan Water Board. The potential of the requirements approach to allocate society's resources efficiently is assessed. The price variable is suggested as a means of exercising water demand management and the second objective is to compare the efficiency of a marginal cost pricing approach with the requirements approach in terms of resource allocation.

Finally, no matter how superior a marginal cost pricing policy may be to the present flat-rate policy theoretically, it needs to be proven that the costs involved in implementing such a scheme do not outweigh the benefits. To this end, a cost-benefit analysis is conducted to determine whether or not universal metering should be introduced in Hobart.

The cost-benefit analysis implicitly compares the two alternatives available to water authorities to meet demand after 1978/9 when the present supply is expected to reach full capacity. These are whether to duplicate the Derwent Water Supply Scheme and thus continue the flat-rate method of charging or to introduce metering and to implement a marginal cost pricing policy. The cost-benefit study measures the costs of accepting the latter alternative and matches them against the benefits which are in fact the savings that would accrue from rejecting the former proposition.

The study incorporates a modified version of Williamson's model which is designed to determine when capacity (with the indivisibility constraint) should be expanded under a marginal cost pricing policy. This is necessary in order to estimate the savings that would result from deferring capital expenditure on a new pipeline.

The introductory chapter covers the first two objectives of the study. It is argued that the price variable, properly used, would be an effective tool for demand management with the ultimate aim of achieving an efficient allocation of resources. The chapter also discusses some of the limitations of a marginal cost pricing rule.

Chapter 2 provides the analytical framework for the cost-benefit analysis. The choice of the cost-benefit tool and its superiority over traditional methods of evaluating projects are discussed. The rationale behind Williamson's model for developing appropriate investment criteria is explained.

In Chapter 3 the assumptions underlying the cost-benefit analysis are spelt out. It is believed that the dependability of the results rests ultimately on the validity of the assumptions made. Hence, a proper justification of each assumption is necessary. The chapter also explains how a demand function for excess-water was improvised for Hobart in the absence of a marginal pricing system.

Chapters 4 and 5 are concerned with the quantification of the costs and benefits respectively of metering. Calculations were done under two alternative assumptions regarding future growth in the demand for water. Also, four discount rates were employed for sensitivity analysis.

Chapter 6 presents a summary of the results and the conclusions of the study. The cost-benefit analysis showed that metering in fact is preferable to duplicating the trunkline. It is concluded that although the State government appeared adamant in its intention to proceed with the pipeline project, this study would hopefully serve to indicate the type of analysis that could assist in making the optimal decision when faced with a similar situation in future.

Acknowledgements

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CHAPTER 1

INTRODUCTION

1.1 Objective

In 1977 the Metropolitan Water Board, which is responsible for the supply of water to Hobart, made a submission to the Tasmanian Parliament with the proposal to install water meters in the Metropolitan Area. Submissions were also made subsequently by the municipal Councils in the Metropolitan Area which generally opposed the Board's idea. Eventually the Metropolitan Water Board's proposal was rejected by Parliament.

The objective of this study is three-fold. Firstly, it is to examine the present philosophy behind Hobart's water supply. An assessment is made of the investment criteria used by the Metropolitan Water Board, a public enterprise producing an economic good (water). Secondly, it is to evaluate the advantages of that enterprise adopting an alternative basis for decision making. It is argued that a marginal cost pricing system would provide a more efficient basis for investment decisions. Finally, having compared the existing policy with the suggested alternative, the feasibility of exercising demand management of Hobart's water resources through the price variable is examined. This entails a reconsideration of the Board's proposal to meter consumers.

1.2 Hobart's Water Supply System

Under the Metropolitan Water Act (1961), the responsibility of providing a continual supply of water to the Metropolitan area of Hobart was vested in the Metropolitan Water Board (MWB). This area comprises the cities of Hobart and Glenorchy, and the urban portions of Clarence and Kingborough municipalities. The noteworthy feature of Hobart's water supply system is that its two

If it is assumed that water is a 'special' commodity, one whose consumption should not be inhibited by such factors as price, then perhaps the requirements approach can be justified. The unrestricted availability of water for both domestic and trade purposes undoubtedly assists the growth of the urban areas. In this respect the traditional policy of Hobart's water supply authority deserves credit; Hobart has experienced fairly rapid development and the standard of living enjoyed by its people is comparable to that of any other major city in Australia.

1.4 Need for Demand Management

In the present context however, the requirements approach to the supply of water is untenable for Hobart. Whilst it was once possible to expand supply at a relatively low cost, the cost of further augmenting capacity has increased sharply. As seen above, to expand Hobart's water supply any further would require the construction of pipelines which extend over great distances and possibly the enlargement of storage and pumping facilities. This increase in the cost of providing a ready supply of fresh, clean water at the tap has forced a change in the conceptual view of water:

> "Water has evolved from a free good, an item that can be enjoyed without foregoing other resources, to that of an economic good, in which sacrifices of other goods are required. The term 'economic good' carries with it the connotation of relative scarcity, which is a reflection of the interplay between wants and sources". [24, p.1359/60].

If this view is accepted, then it is only logical that water be treated in the same way as other economic goods.

In a situation where various economic goods are competing for limited investment funds, the criterion behind the requirements approach is clearly inefficient as a basis for decision making. Under the present system, the marginal cost of use of water is zero (or negligible), whilst the marginal cost to provide water is relatively high. This is a characteristic feature of a flat-rate pricing system. Referring to this system, Rees has pointed out that it is a basic barrier to economic efficiency in the performance of water undertakings,

> "....the water they supply is typically underpriced, their capacity overexpanded, and resources (water, construction equipment, land and labour) are being diverted away from uses valued more highly on the margin by consumers.....There appear to be no rational grounds for allowing water supplies to be extended to meet all forseeable 'needs', when the supply of most other commodities is only increased when the consumers are prepared to pay for the increase by foregoing alternative goods." [41,pp.21, 28].

The 'externality' argument is sometimes forwarded to support the present philosophy behind Hobart's system of water charging and investment in supply capacity. This argument stems from the fear that if a payment-by-use scheme is introduced, the use of water will be deterred with consequent harmful effects on peoples' health. Looked at in the context of an affluent society, the argument is not convincing.

> "For one thing, the fear that individuals will endanger their own health presupposes a degree of irrationality among consumers that is probably unjustified - and in this particular case, this will take care of the externality problem as well." [48, p.230].

Furthermore, the attitude that water is a commodity possessing a 'unique importance' has been challenged. As Hirshleifer has pointed out, food and clothing are also vital to life and yet we have adjusted to the idea that the purchaser must be prepared to pay the going price to satisfy his wants. [26, pp.4-5].

Another criticism of the flat-rate method of charging for water is that it encourages wasteful use. The optimisation of consumer satisfaction requires that an individual purchase additional units of any item until the incremental benefits equal the incremental costs to the consumer. This means that the unmetered user in Hobart takes water until the marginal value is zero. Correction of wastage would impose costs upon consumers without yielding them benefits. [49, p.178]. Seen as a commodity the provision of which requires use of scarce public funds, the efficient use of water is necessary for economic efficiency. A comparison of domestic water demands in Hobart, the West Tamar Water Supply and the North Esk Regional Scheme reveal that the quantity of water used per connection is much higher in Metropolitan Hobart than in the metered Northern areas of Tasmania (see Appendix 1). It is argued, therefore, that in the face of increasing demands and costs it is becoming more important to enquire whether the optimal allocation of resources through (marginal) pricing is relevant to planning and management in this field. It is important to ascertain to what extent consumers are prepared to pay the incremental cost that an addition to the water supply system necessitates. [40, p.157].

Ciriacy-Wantrup [13] concluded that conventional 'requirements' calculations may yield a satisfactory result only if two necessary and sufficient conditions apply:

(i) constant costs,

(ii) perfectly inelastic demand.

In the case of Hobart, it is difficult to prove that either of these conditions is met. Considering the fact that the costs of future expansions to the city's water supply system are more likely to increase than remain constant, an upward sloping long run marginal (and hence average) cost curve would exist. The main reason why this is so is that as water consumption increases, the Board (MWB) might find it necessary to exploit sources that are less and less accessible.

As for the price elasticity of demand for water, *a priori* it is impossible to determine in the absence of a price structure based on consumption. Studies conducted in other countries yield no conclusive results. However, the experience of the West Tamar may be relevant for Hobart, since the climatic and other factors affecting demand for water are not significantly different in the two areas. Before metering was completed, the average daily demand per connection in the West Tamar area was 1 100 (1962/3), 1 310 ('63/64) and 1 810 ('64/5) litres. Upon completion of the metering scheme and implementation of an effective pricing policy, "average demands have been between 1 300 and 1 500 litres per day". [7, p.4]. Based on this and similar experiences reported in other parts of Tasmania (e.g. Burnie, North Esk area), it is hypothesized that the price variable would in fact have a bearing on the consumption of water in Hobart.

1.5 Price Variable as a Tool of Demand Management

The 'requirements' approach as argued above, generally leads to wasteful use of water and inefficient allocation of resources. In order to overcome these shortcomings, clearly some form of urban water demand management is needed. Gallagher and Robinson recently reported that

> "water price, through the water demand function, has the potential to be an effective policy tool in the hands of innovative water supply authorities. Through the adoption of an appropriate water price policy, water supply authorities should achieve more effective and efficient control of water supply and water use". [19, p.1].

Under certain restrictive conditions[2], it can be shown that

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2. According to Collard [14, p.71] these conditions are:
   (i) Conditions appropriate to perfect competition prevail throught the whole of the rest of the economic system.
   (ii) Consumers are best judges of their own interests,
   (iii) The distribution of incomes is equitable,
   (iv) There are no relevant externalities.

efficiency in output for a public (as well as private) enterprise is achieved by equating price with the marginal cost of production[3]. Warford [48, pp.219-222] also shows how a marginal pricing scheme can be utilised to formulate criteria for investment in capacity. These criteria involve an explicit assessment of the value of the additional water made available. New investment in capacity (for the case of perfect divisibility) is justified only when quantity demanded exceeds the point where price equals short and long run marginal costs.

Marginal cost pricing has certain limitations the discussion of which is well documented in the literature. (See for example 14, ch. 8). Suffice it to say, these limitations can be overcome by pricing policies which are at best, modifications of the marginal cost pricing rule. For example, under certain conditions, a marginal cost pricing policy would result in the enterprise making financial losses. This problem can be overcome by imposing a 'two part tariff' whereby the consumer pays a fixed charge per period plus a charge that varies with the amount used.

Perhaps the most serious doubt related to the marginal cost efficiency principle has become known in the literature as the problem of 'second best'. The Second Best Theorem proves that if any of the conditions for Pareto optimality[4] under the marginal cost pricing rule are not met, then in general, equating price with marginal cost may not produce the allocative efficiency desired. [31]. Under circumstances where prices everywhere are not equal to marginal costs, the welfare maximisation problem has to be reformulated and an alternative optimal pricing policy

3. See for example Henderson and Quandt [23].

4. A Pareto-optimal (or socially efficient) allocation of resources is one which cannot be altered without someone being made worse off. [12, p.1].

derived. The way in which the alternative solution is obtained has been dealt with in the literature [see for example 9 and 11]. The point of concern to us here is how serious is the second-best problem in regard to the public enterprise producing water.

Davis and Whinston [17,18] have explored the conditions under which a 'piecemeal approach' to policy is justified, i.e. formulating a marginal cost pricing policy for the economic enterprise under study when the Pareto conditions may not be fulfilled in some other parts of the economy. Briefly their view is that

> "in determination of appropriate pricing policies that which is not known about the fulfilment or not of the optimum conditions elsewhere in the economy should be ignored. But that which is known and is important should be taken into account." [50, p.46].

Now, we know that water is both a final good to households and an intermediate good to industries. However, it may be argued that since most water is supplied to households, the pricing behaviour of firms may not pose a serious setback to achieving efficiency through marginal cost pricing. On the other hand, we could assume that the majority of products used by households, which may be either complements or substitutes of water, are priced above their marginal costs. Hence, with the marginal price of water currently set at zero (i.e. well below the marginal cost) we have a sub-optimal situation. The sub-optimality arises because there is an over-use of the complements of water (and hence the resources employed in their production) and an under-use of the substitutes of water (with a consequent under-use of the corresponding resources).

Therefore we argue that a movement of the price of water towards the true marginal cost would have the effect of reducing the sub-optimal bias in the economy, although it is still unlikely that the resulting situation will be Pareto-optimal.

The other method of exercising management of water demand is of course by imposing restrictions on the use of water at certain times. These restrictions (e.g. cutting off of supplies or reduction of pressure) could have severe disruptive effects on productive processes and impose a threat to public hygiene and health, which "could in principle be quantified, but there is a prima facie case for supposing that the costs entailed would outweigh those of, for example, the installation of domestic meters". [48, p.225].

As Grima [22, p.6] concludes,

> "It is preferable to use price as an instrument of policy in such a way as to reduce those uses of residential water that the consumer values less than the cost to the community of providing the service. This approach leaves the consumer with the choice of exercising his right to buy more water at a price that reflects its cost; at the same time the management makes use of non-arbitrary criteria in attempting to allocate resources efficiently to the development of residential water supplied."

1.6 Definition of Problem

A payment-by-use system, while superior to the present system in Hobart on the grounds of efficiency is, however, not cost-less to implement. Certain costs must be incurred if demand management is to be exercised through an effective price mechanism. Therefore, in what follows, our chief aim is to enumerate and measure these costs and to weigh them against the benefits derived from removing or reducing wasteful use of water in Hobart. Since metering is the sole means of implementing any pricing policy based on consumption, our fundamental question becomes:

<u>Should Hobart's water consumption be metered?</u>

As explained in the next chapter this question can best be answered through the application of cost-benefit analysis techniques.

CHAPTER 2

THE FRAMEWORK OF ANALYSIS

2.1 Cost-Benefit Analysis

Cost-benefit analysis is coming to be applied to a wide variety of public projects to determine their economic feasibility.

> "By marshalling data systematically, putting it in quantitative terms wherever appropriate, and rendering it as commensurable as possible, it lays bare the considerations relevant to a complex decision in a manner which provides policy-makers with a much more intelligible and comprehensive view of the situation than is possible by any other means." [47, p.3].

The cost-benefit approach differs from the traditional methods of investment appraisal (used mainly by the private sector) in that it emphasizes the social costs[5] and benefits attributable to the project. The older methods on the other hand tend to restrict themselves to just the financial considerations. In general a public project gives rise to intangible costs and benefits which should be given due consideration if the true economic and social worth of the project to society is to be determined. As such the methodology of cost-benefit analysis is most appropriate for examining the public project under discussion in our study, i.e. metering of Hobart's water supply.

Extensive use of the cost-benefit approach has been made in the field of water resources, where the occurence of secondary effects is a characteristic feature. Of special relevance to the metering issue, however, there exist only a few studies of recent date. This is possibly due to the fact

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5. 'Social costs' have been defined as the "sum total of the costs of an economic action." [39, p.18]. By this definition, they would include private costs which are those costs that affect the decisions of the performers of the action.

that most large cities (at least in Australia and the U.S.) have had their water supplies metered for a long time. Of those examined, the one of New York's water supply seemed most pertinent to our situation. In New York's case too the authorities were faced with supply operating at capacity and the dilemma of whether to make more efficient use of existing supplies through metering or to expand capacity by the building of a new dam.[6] The approach in the present study is broadly similar to that in the latter, with certain modifications to suit our purposes.

2.2 Existing Studies of Hobart

The Metropolitan Water Board first approached the metropolitan councils on the question of metering in 1964. Subsequent approaches were made in 1966, 1969, 1973, 1974 and finally in 1977 its proposal was debated in Parliament. These submissions (at least the last four) were accompanied by the MWB's financial calculations which, based on the premise that the immediate installation of meters would defer the need to invest in additional supply capacity, generally produced the result that metering was cheaper than maintaining an unmetered supply system.

The MWB also engaged consultants "to undertake a comprehensive economic and engineering study of the metering proposal" in 1974 [3, p.6]. This study arrived at the conclusion that

> "an early investment in a trunkline, without any reduction in consumption ... is favoured over solutions with reduced consumption due to the installation of a universal metering system."[7]

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6. The Rand Study. See [32, pp.69-72]. Other cities where an economic evaluation of metering was carried out are for example Toronto and Etobicoke, both in Canada [22].

7. Report by W.D. Scott and Co. Pty. Ltd. [8, p.16]. Henceforth referred to as the Scott Report.

The findings of the consultants were not accepted by the MWB for three main reasons:

(i) the MWB did not agree with the "unrealistic" assumptions of future inflation made by the consultants, which had a significant effect on their results,

(ii) the consultants had not considered the national or state priorities in the allocation of funds for capital works, and

(iii) the failure to account for the expenditure which would be required to distribute the additional supply of water (from a new trunkline) to households. [3, pp.6,7].

The other major economic study of the issue, conducted by the Hobart City Council (HCC), was contained in its submission to the Parliamentary Standing Committee on Public Works [2]. It supported the findings of the Scott Report with its own cost calculations of the two alternatives: metering or building a new trunkline. This report raised a number of issues regarding the technique and data used by the MWB in its calculations. The MWB in turn questioned the way in which the HCC had conducted its present value calculations [4]. In this study we aim to examine some of these theoretical issues and to extend the analysis, taking into account any intangible gains and losses through metering.

2.3 Nature of Costs and Benefits

Faced with the question of whether or not Hobart's water supply should be metered, clearly an objective approach would be to weigh the benefits of such a scheme against its costs using the cost-benefit tool. This is precisely the analysis carried out in the present study. In attempting to answer the question above we shall be making the implicit assumption that the alternative to metering consumers is to duplicate the Derwent Water Supply pipeline immediately. Therefore, should the measured benefits of metering fall short of the costs involved (all in money terms), the correct decision would be to proceed directly with the construction of the new trunkline and consider metering an uneconomic proposition.

Because we are considering only the two alternatives, namely metering and non-metering, the 'benefits' of the metering project would consist of the costs of the non-metering project not incurred. In other words, the benefits of metering Hobart's water supplies are the negative costs of constructing the new pipeline and allowing an unrestricted use of water at zero marginal cost to the consumer.

In this section, we shall outline broadly the costs and benefits which will enter our analysis. Table ~~2~~ 1 below lists the cost and benefit items, following which are some explanatory remarks on each item. These are then quantified in Chapters 4 and 5 to follow.

TABLE 1

Costs and Benefits of Metering Hobart's Water Supplies

	Costs		Benefits
C1	Purchase and installation of meters.	B1	Non-installation of new pipeline
C2	Reading, Billing and Maintenance of Meters.	B2	Non-imposition of restrictions before completion of new pipeline
C3	Loss of Consumers' Surplus	B3	Avoidance of operational costs of producing excess water with new pipeline.
C4	Operational Costs of producing excess water.		

COSTS:

C1 Purchase and Installation of Meters

The capital cost of the project comprises the material cost of household meters and the labour cost of installation on premises. It is believed that full-metering in Hobart (i.e. the metering of every connection, with the exception of certain places like lock up shops, etc.) can be achieved over a span of 3-4 years, requiring an estimated 46 000 domestic meters. Once universal metering is attained an additional number of new meters would be needed each year for new connections.

C2 Reading, Billing and Maintenance of Meters

Personnel would have to be employed to read meters regularly, bill customers and conduct maintenance work on faulty meters. These activities could be performed from a centralised office to minimise administrative costs. This also implies that all the municipalities to be metered could be served from the one office. Costs in this category would be incurred directly after the installation of meters, i.e. from the first year of the metering program. Thus, while part of the Metropolitan Area will be charged for their usage of water, other parts will still be charged on the basis of their property rates. As commented in the Scott Report [8, p.13], this is standard practice elsewhere and if the installation is carried out by homogeneous geographic areas, it would be more acceptable to consumers.

C3 Drop in Consumers' Surplus

This cost is based on the notion that an increase in the marginal price of water from zero to a positive value will lead consumers to consume less water. In doing so, the consumers would be incurring a loss of what has been termed 'consumers' surplus' in economic theory. The concept was first expounded by Alfred Marshall [33, Ch. 6]. He defined the consumer's surplus as "the excess of the price which he would be willing to pay rather than go without the thing, over that which he actually does pay". [33, p.124].

Consumers' surplus is usually measured by the area under the demand curve and above the prevailing price level, as illustrated below. We note here a peculiarity of the demand for water in the regions covered by our study. As in other capital cities around Australia, households in the metered areas of Tasmania pay two rates for the water they consume: a minimum charge annually for a fixed amount of water known as the 'basic allowance' and a price per unit of water consumed in excess of the basic allowance. A demand curve drawn for an area with such a pricing system will necessarily apply only to the 'excess water' consumed. The use of an excess-demand curve in place of a total-demand curve does not affect our analysis of consumers' surplus as long as we assume

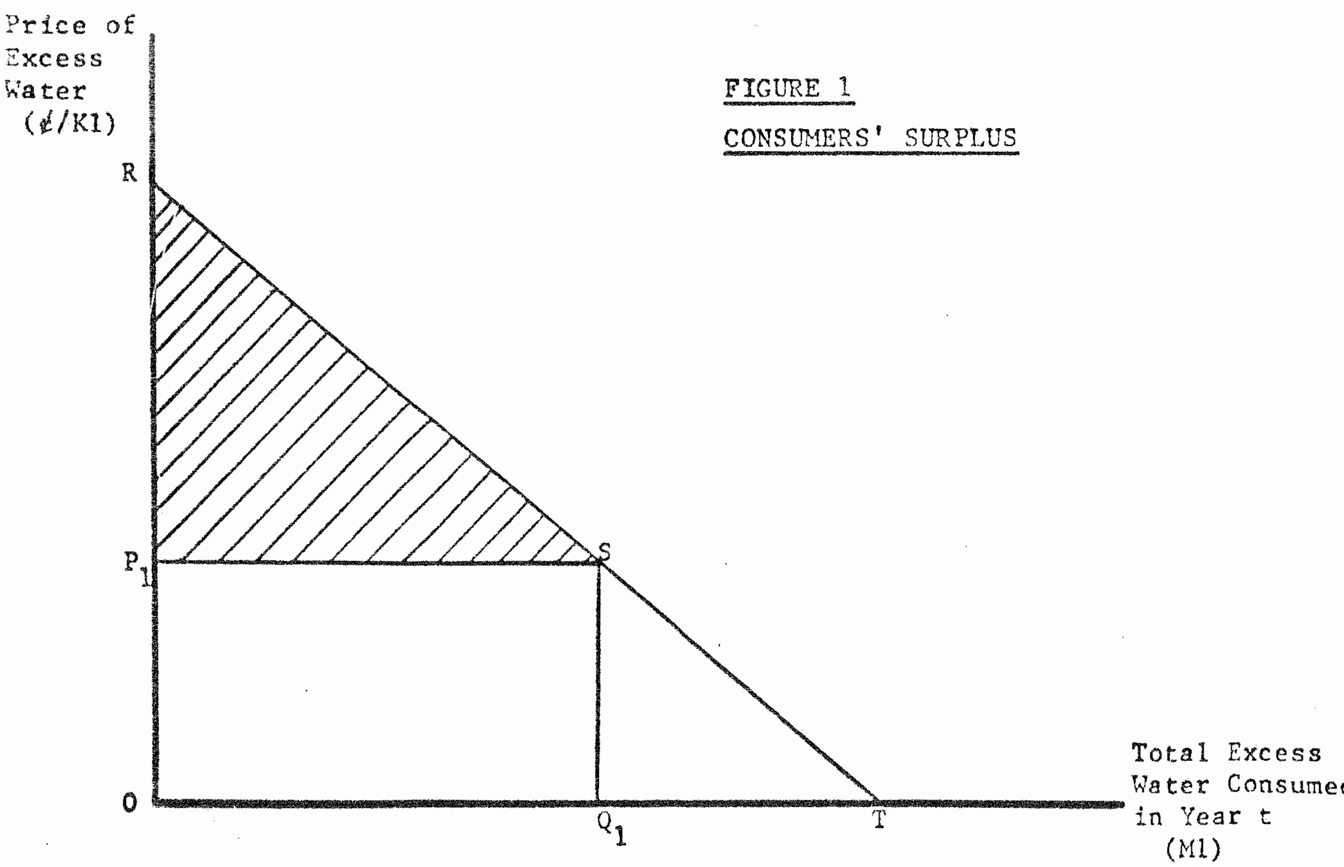

FIGURE 1

CONSUMERS' SURPLUS

that the imposition of a marginal price for excess water will only curtail the use of excess water and leave the consumption of the basic allowance unchanged.

In Fig. 1, consumers purchase quantity Q_1 of excess water, in year t say, at the prevailing price P_1. The section RS of the downward sloping demand curve shows however that they would have been willing to pay higher prices for quantities of water less than Q_1. The net advantage to consumers of being able to buy all their desired units at price P_1 is therefore represented by the shaded triangle, P_1SR.

Assuming the quantity of excess water consumed in the absence of metering was OT (price is zero) and after metering is OQ_1, the change in consumers' surplus is shown by the area $OTSP_1$. However, consumers now pay a total of OQ_1SP_1 for the excess water they consume. The net loss in consumers' surplus, the amount we are concerned with in our analysis, is therefore the area Q_1TS. This is correct, strictly, only if certain assumptions underlying the theory hold. These assumptions are detailed in the next chapter.

The rationale for including this cost in our analysis is based on the fundamental principle that in carrying out a benefit-cost analysis, one should try to estimate all of the benefits and costs of the project in question. [34, p.344]. Due to the statistical problems involved in measuring consumers' surplus however, it is not unusual for analysts to ignore the concept altogether in their calculations. Strongly defending the importance of the concept, Mishan has said that "without attempts to measure increments of consumers' surpluses, ...cost-benefit analyses would be primitive indeed". [36, p.325]. A common criticism may be made of the three existing studies of Hobart (cited above) for failing to estimate the drop in consumers' surplus.

C4 Operational Costs of Producing Excess Water

The operational costs of supplying potable water consist mainly of the pumping and treatment costs. Water has to be pumped by electrical pumps and part or all of it treated with chemicals before it is reticulated. Obviously the higher the consumption level, the greater the volume of water that has to be pumped and chemically treated and thus the larger the operating expenses.

If metering were introduced, the total operational costs of producing water are less than they otherwise would be because of the reduced quantity of 'excess-water' delivered at a positive marginal price.

BENEFITS:

B1 Non-installation of New Pipeline

The latest report on the scheme to build a new trunkline for Hobart's water needs states that without meters work on the duplication of the Derwent Water Supply Scheme would have to start as early as 1978/9 [5, p.1]. Additional investment expenditure would be outlaid over a ten year period before the pipeline to Hobart is complete. This pipeline would then be adequate to meet the demand until sometime in the 1990's, the exact year depending on the forecast of future water consumption trend. (See Fig. 3, p. 22).

Assuming that under metering, the consumption of water could be reduced, the existing capacity would be sufficient to meet demand for a longer period of time, hence postponing the necessity to augment supply to a later date. The capital cost of installing the new pipeline would thus be saved if the metering project is accepted.

B2 Non-imposition of Restrictions Before Completion of New Pipeline.

Because the demand for water in Hobart is expected to meet the present supply capacity during the summer of 1978 and work on the proposed new pipeline is not expected to commence until 1979 due to the delay in obtaining loan funds, the MWB has had to plan a program of restrictions on the use of water to reduce the summer demand. The program is expected to last five years and seven inspectors are to be employed, whose duty would be to ensure that consumers do not infringe the restrictions. The annual cost of imposing restrictions consist of the salaries paid to the inspectors and other administrative and publicity expenses. Since the metering project itself takes about three years to complete, the savings on restrictions that enter our analysis correspond only to the latter two years before the first stage of the new pipeline becomes operational.

B3 Avoidance of Operational Costs with New Pipeline

Under the present system of charging for water, no distinction is made between the basic allowance and what is consumed in excess of that allowance. However, referring to Fig. 1, we notice that the amount of excess water consumed when the price is reduced to zero is OT units. This situation is in fact no different from the present system of charging a flat rate for unlimited use. Hence we may speak of the 'excess water consumed' under the non-metering system.

Now, as mentioned earlier, without meters, a greater volume of water may be expected to undergo pumping and treatment procedures, hence increasing the operating expenses bill. This negative cost constitutes another benefit of accepting the metering proposal instead of the new pipeline.

2.4 Need for New Pipeline With Meters

One of the benefits of metering mentioned in the previous section was the costs that could be saved if investment in the new pipeline is delayed. Measurement of these savings therefore requires the determination of the time gap between building the pipeline now, without metering, and later, under a marginal cost pricing system. To do this, we employ a modified version of the model developed by Williamson [52]. The modification is necessary because of the existence of a two-part tariff in our situation. By this is meant that a fixed charge is levied for the 'basic allowance' of water per household above which a price per unit of water applies. Instead of 'total amount of water consumed', our analysis is conducted in terms of 'total amount of excess water consumed'.

Fig. 2 below illustrates the rationale of the model.

FIGURE 2

MODEL TO DETERMINE WHEN PIPELINE SHOULD BE BUILT

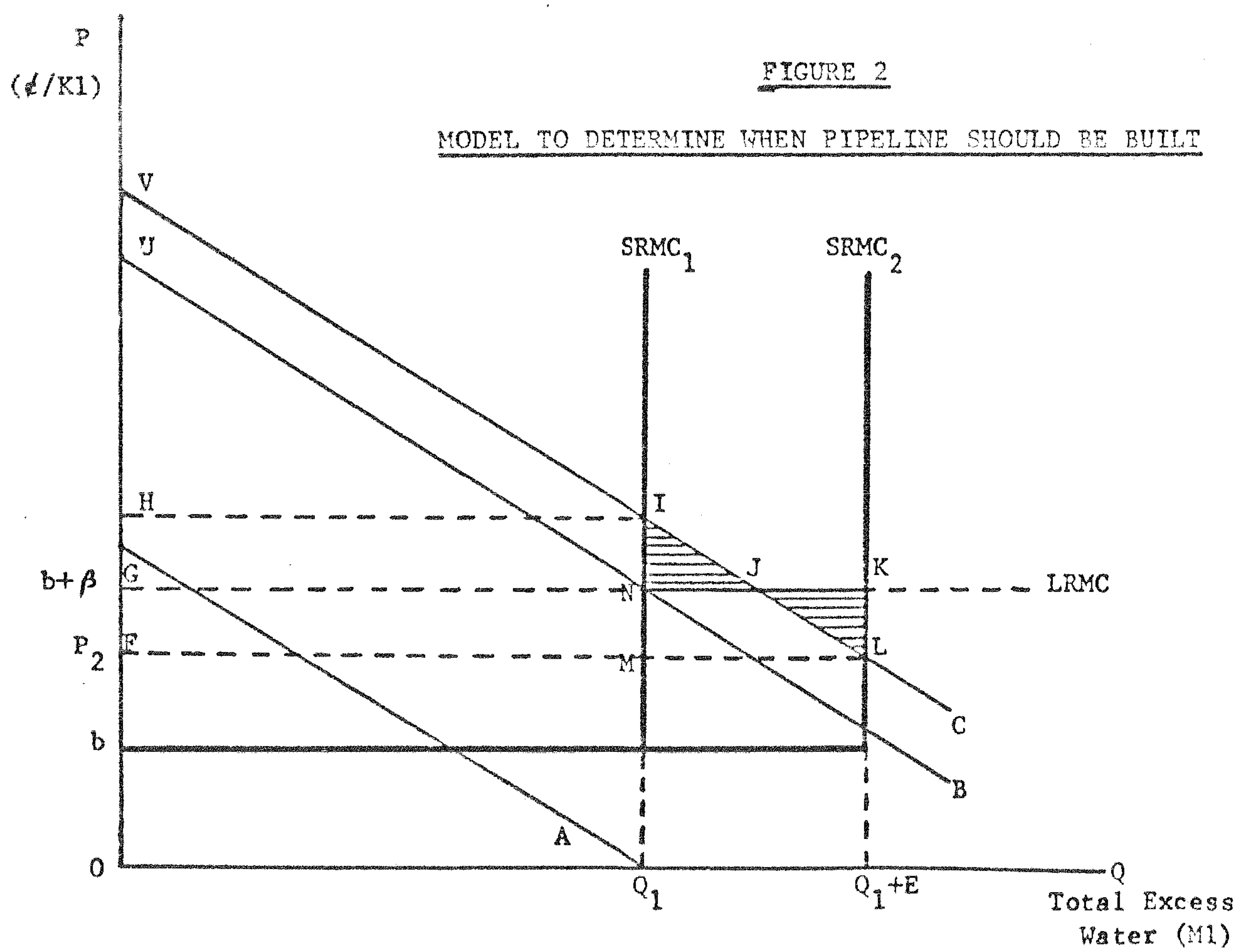

Figure 2 shows that the demand curve for excess water, assumed initially in the position A, gradually shifts away from the origin as the population and affluence of consumers increase each year. These factors are conveniently represented by the number of connections[8] in the excess annual demand function for water formulated for the analysis:

$$Q = f\ (C, P, R, S)$$

where Q = total excess water consumed during that year (in Megalitres).

C = number of connections in that year

P = real price of excess water (in ¢/Kilolitre, 1966/7 prices)

R = total rainfall during the period October-February (in mm).

S = 1, if restrictions were imposed on water consumption in that year

= 0, otherwise.

Estimation results of the above function are presented in Chapter 4.

The position of the demand function in any year can thus be obtained by maintaining the variables C, R and S at appropriate values and varying the price P.

The model also involves estimation of the short-run and long-run marginal costs of producing water. The short-run marginal costs (SRMC) are assumed to be the marginal operating costs of pumping and treating water. These are assumed to be constant, at a rate of b (¢/Kl), as long as output is less than

8. The Rivers and Water Supply Commission [7, p.2] argues that it is the household rather than the person which most significantly incluences demand, "because there is little difference in drawoff for such matters as washing machines, car cleaning, gardening and lawns whether there are 3 or 4 persons in a house". Furthermore we assume that with growing affluence, the number of persons per household would tend to decline whilst the number of properties with water connections (e.g. holiday shacks) would increase. It is contended therefore that the number of connections is superior to other variables such as annual income or total population in explaining the consumption trend of water.

capacity. "When capacity is reached, however, marginal operating costs become effectively infinite. Thus a sharp kink develops at the existing capacity level". [52, p.68].

Because we are concerned with excess water demand a method was devised to provide the analogous levels at which the SRMC curve becomes vertical. This method requires the use of the demand function formulated above and Fig. 3, which shows the projected demand on Hobart's water supply system in summer. The two curves show the unrestricted demand in a dry summer (i.e. average summer demand plus a 10% safety margin). The 'High Estimate' and 'Low Estimate' curves are drawn on the basis of high and low forecasts respectively of the number of households connected to the water supply system after 1978/9. (See Section 3.6 for further explanation). The diagram indicates that the present supply system will be operating at capacity in the summer of 1978/9. With a new pipeline, such as the one proposed as the alternative to metering, Hobart's water supply capacity would be enhanced (broken line) and from the diagram we can determine that demand will equal supply again under the High Estimate in 1991/2 and under the Low Estimate in 1995/6.

We have assumed that the excess demand function will shift away from the origin as the number of connections increases every year. Assuming there are X connections[9] served by the system in 1978/9, we can estimate the 'total excess water' consumed in that year by substituting the appropriate data into the estimated excess-water demand function (i.e. $P = 0$, $R = \bar{R}$, $S = 0$, $C = X$)![10]

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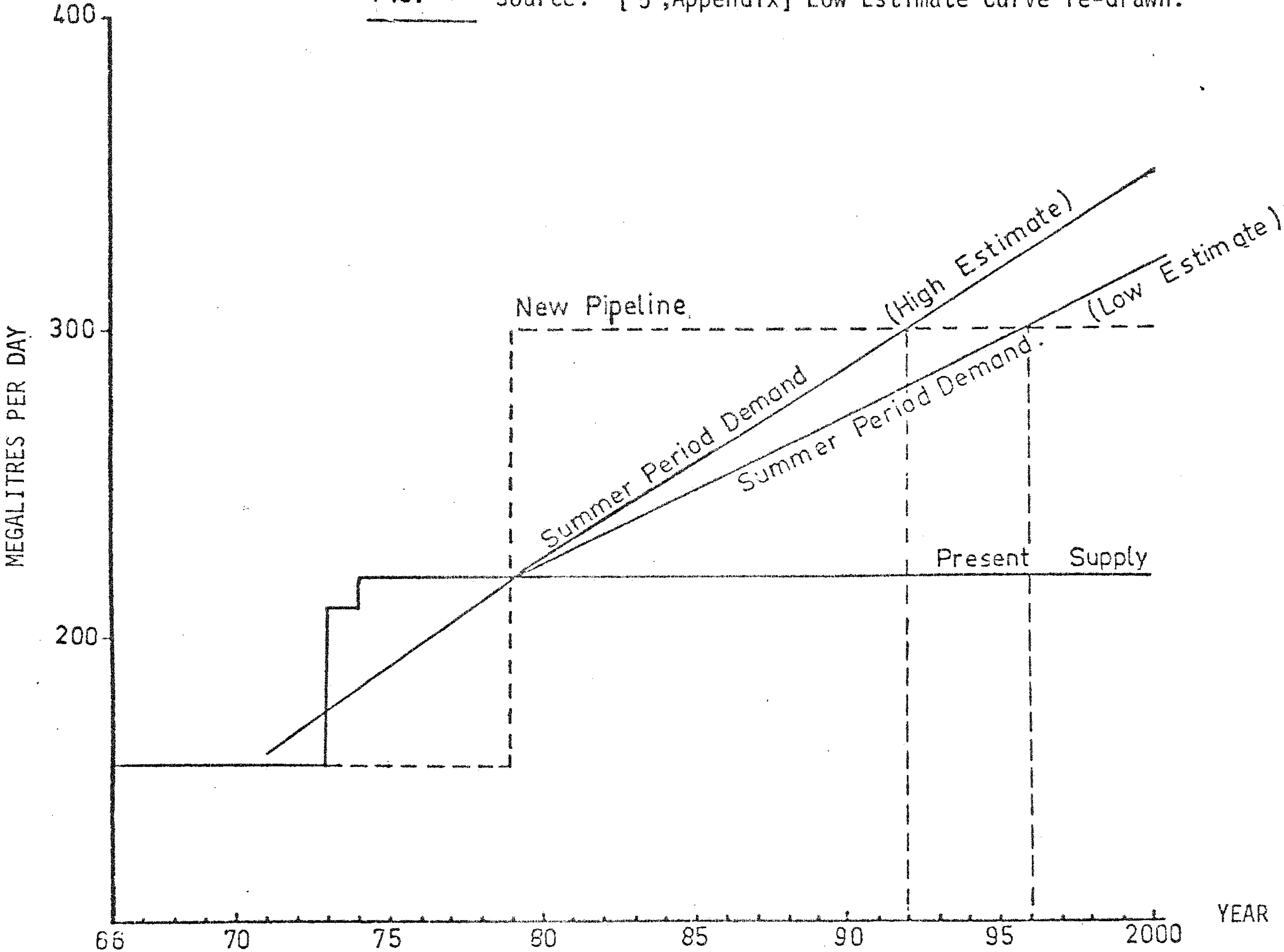
9. It is estimated by the MWB that there would be 44 616 properties in the Hobart area by the end of '78/9 served by the present supply system. [5, Appendix].

10. Rainfall is set at the mean value for a 'dry summer', assuming water authorities plan to meet peak summer demand plus an allowance for dry summer contingencies. See Section 4.1 for definition of 'dry summer'.

FIG. 3 Source: [5 ,Appendix] Low Estimate Curve re-drawn.



SUMMER PERIOD SUPPLY & DEMAND

This is shown in Fig. 2 by the intercept Q_1 of demand curve A on the horizontal axis. Consequently, we assume that that in fact will be Hobart's position in 1978/9.

The new pipeline will cause the vertical section of the short-run marginal cost curve to shift to the right, by say E units of output. The High Estimate Curve in Fig. 3 tells us that the new pipeline will achieve full-capacity operation in the summer of 1991/2. Thus the position of $SRMC_2$ can be determined by substituting the values $R = \bar{R}$, $S = 0$, $P = 0$ and the estimated number of connections at the end of 1991/2 for C into the estimated excess-water demand function. The same procedure may be used if the analysis is to be undertaken with a different assumption regarding future number of connections served (e.g. the Low Estimate Curve).

The formula that has been used to express short-run marginal costs (b) for water is:

$$b = \frac{1}{6} \Sigma \frac{\Delta V_t}{\Delta Q_t} \qquad t = 1983/4, \text{'}84/5, \ldots\ldots. \text{'}88/9.$$ [11]

where: ΔV_t = increment in operating expenses for year t,

i.e. $V_t - V_{t-1}$

ΔQ_t = increment in annual demand for year t,

i.e. $Q_t - Q_{t-1}$

The long-run marginal cost (LRMC) of supplying water is defined as the sum of the marginal operating costs (b) and the average capacity costs (β) of a fully utilized new pipeline, i.e. LRMC = b + β. β in turn comprises the average annual

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11. The years 1983/4 - 1988/9 were chosen because the new pipeline, in the absence of metering, will come into operation in 1983/4 assuming work begins in 1979/80. [5, p.1]. This formula therefore provides us with a 'forward-looking' estimate of marginal costs instead of a figure based on historical data. [see 44, p.10].

maintenance cost of the new pipeline and the quantity $\frac{R}{Z}$. R is the amount paid annually over the useful life of the pipeline by an equivalent risk annuity foregone as a result of investment in the pipeline and Z is the total capacity of the new pipeline, in our case 150 Ml/day.

With the above formulation of the model, Williamson's analysis goes on to show that a new output unit (i.e. pipeline) should be added when the area IJN in Fig. 2 just exceeds the area JKL <u>and not before</u>. Suppose these two areas are equal when the excess-demand function is in position C.

The basis of this optimal-capacity condition is derived from welfare theory. Briefly, it rests on the assumption that social benefit is to be maximized. This may be achieved with the aid of a Social Welfare function of the form:

$$W = S + (TR - TC)$$

where the first term is the consumers' surplus and the second term (Total Revenue minus Total Cost), the producers' net revenue (referred to by Williamson as 'producers' surplus'). Reverting to Fig. 2, consider the position C of the excess-demand function. By definition, producers' surplus will be given by HING and consumers' surplus by VIH. Thus, the welfare gain will be VING. Suppose the additional pipeline is built; marginal cost pricing will dictate the price P_2, causing producers' surplus to decrease by the amount (HING + GJLF + JKL) while consumers' surplus increases by (HING + GJLF + IJN). The net gain is IJN -JKL, which clearly is zero. Hence, from a welfare point of view, one is indifferent to whether capacity should remain at Q_1 or be increased to $Q_1 + E$. But whenever IJN > JKL, the net welfare gain will be positive, in which case the new pipeline should be added.

Compared with the above analysis, the existing studies presume that new supply units should be added whenever the existing system reaches the point of operating at full capacity, i.e. as indicated by the supply and demand projection in Fig. 3. Following that approach, it is contended that a pricing system, even if implemented, would not be made use of to the best advantage to society.

It is to be noted that the analysis above holds strictly only under the assumption that there is a single uniform class of demands and indivisible output units. For an item like water, which experiences a periodic load demand, Williamson provides an extension of his model, incorporating separate periodic demand curves. Unavailability of essential data did not permit us to employ the periodic-load analysis in our study. However, it is contended that this does not seriously alter the basic results of the present analysis. As Williamson points out, "the analysis of periodic loads differs only in degree and not in kind from the.....uniform-load problem". [52, p.82].

The advantage of our approach over the previous studies is not only that it shows correctly how long the deferment of investment in the new pipeline will be through metering, but also it provides us with a firm pricing policy which is welfare motivated.

CHAPTER 3

ASSUMPTIONS

3.1 Consumers' Surplus

In Section 2.3, the concept of consumers' surplus was depicted by the shaded area under the demand curve. Now this is true only under the assumption that water is a commodity with zero income elasticity [25, pp.193-195; 32, p.69]. Alternatively consumers' surplus can be represented by the area P_1SR in Fig. 1 for a good whose income elasticity is not 0, if the demand curve employed is the 'income-compensated' (or Hicksian) demand curve. The income-compensated demand curve is different from the 'ordinary' (Marshallian) demand curve in that it excludes the income effect of price changes while the latter incorporates it.

We assume that an approximation of the income-compensated demand curve may be obtained by estimating a general linear demand curve with income and price among the demand determinants.[12] We have in fact done this by including the number of connections in the excess-demand for water function [Section 2.4]. As would be recalled increases in real income (and affluence) are associated with an increasing number of connections to water supplies.

The other assumption we make in measuring consumers' surplus is that the excess-demand curve for water is linear, at least over the relevant range of prices, represented by OP_1 in Fig. 2.

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12. This assumption is considered reasonable because in allowing for changes in real income in the demand function, we are in fact "eliminating the income effect from the price-quantity data". [25, p.150].

3.2 Demand Curve for Hobart

A demand function for water showing the relationship between quantity and price is necessary for evaluating changes in consumers' surplus and forecasting when the new pipeline ought to be added to the system under metering (see Chapter 2). In the case of Hobart however, such a function is non-existent because of the absence of a marginal pricing system.

One solution to the problem is to conduct a large-scale experiment on a sample of the population whereby the consumption behaviour of consumers is studied under different price regimes. Such an experiment was not feasible within the limits of this study. Besides, this method has its own serious limitations. For example, the sample households would be aware that the 'prevailing' price level is only temporary and this would affect the adjustment of their consumption pattern, producing error-prone data.

The other possibility, adopted here, is to employ data from metered areas that are comparable to the area under study. The areas selected in this study were the North Esk and West Tamar Water Supply Scheme areas in the north of Tasmania. Both schemes together (hereafter referred to as the 'Substitute Area') serve the region encompassing Georgetown and the city of Launceston. Time-series data revealed that climatically there is no significant difference between the Substitute Area and Hobart. In addition, we assume that any difference in terms of standard of living, tastes and preferences of residents in the two areas that might affect their water demand patterns is negligible. Effectively, our assumption implies that Hobartians would behave in the same way under a price system as do the consumers in the Substitute Area.

The excess-demand function, described in the previous chapter, was thus estimated using pooled data from the Substitute Area and the resulting equation was applied to the present problem facing Hobart. (Results of estimation are presented in Section 4.3).

3.3 Pricing Policy under Metering

It will be recalled from Section 2.4 that the model was in terms of 'excess-water' consumption, with the underlying assumption that with metering, a 2 part tariff would be imposed on consumers. Marginal cost pricing would thus affect only what is consumed above the annual basic allowance per household. In line with most metered areas in Australia and even other countries, this pricing system is assumed likely to be implemented if meters are installed in Hobart. A more important reason for employing a 2 part tariff seems to be that it ensures full recovery of costs by the public authority responsible for providing water. The minimum charge for the basic allowance is designed to cover the fixed costs of water supply, which are relatively high because of the large investment required, and in addition some of the fixed operating costs (e.g. maintenance of treatment works, meter reading and billing).

This study does not purport to prescribe what the basic allowance or minimim charge should be but a few important points are mentioned to serve as guidelines for formulating an optimal pricing policy for Hobart's water supply. Firstly, the fixed minimum charge is justified only if the short-run marginal costs are lower than the average costs [22, p.169]. Total expenditure would not be covered by charging only at the marginal price and therefore the fixed charge becomes necessary to raise the necessary revenue. When marginal costs exceed average costs, fixed capital and operating costs, like the variable costs are reflected in the price charged for water and hence a fixed charge is not justified. It would be beneficial from the view of rationalizing the price structure however, to abolish the minimum allowance with the fixed charge and to retain the fixed charge. This would also allow the water authority progressively to reduce the fixed charge, with the ultimate aim of selling all water at a marginal price. The economics of such a pricing policy and others are extensively dealt with elsewhere (see Bibliography for selected references). An optimal pricing policy for Hobart could be developed with further work in this area.

3.4 Comparison of Projects with Different Lifetimes

When comparing a project such as metering Hobart's water supplies with the new pipeline alternative, we are faced with the difficulty of unequal project lives. With meters, the need to augument capacity is deferred to either 1998/9 or 2003/4 according to whether we take the High or Low Estimate assumption concerning future number of connections. This result was determined by the technique outlined in Section 2.4. In other words the estimated excess demand function reaches the position C in Fig. 2, in either 1999/2000 or 2004/5 (Calculations are shown in Chapter 4).

On the other hand, if the new pipeline is built over the period 1979/80 - 1988/9, it will meet expected future demand only until 1991/2 or 1995/6 under the High and Low assumptions respectively, as shown by Fig. 3. Thus additional capacity should become operational in 1992/3 or 1996/7 if restrictions are to be avoided. We therefore have under each assumption a like situation of the need for further capacity expansion but that situation is arrived at in different years.

> "Where the projects being compared do not have equal lives, simply calculating their net present values will not provide management with the information necessary for it to make a decision...." [38, p.112].

There are several methods of analysis which overcome the problem of comparing projects with unequal lives [see 38]. The technique we adopt in this study is one which calculates the equivalent annual cost for each proposal. Thus for the High Estimate assumption for example, we compare the annual equivalent of the total discounted costs of metering over the period 1979/80 - 1998/9 with the annual equivalent of the total discounted (negative) costs of building the new pipeline from 1979/80 - 1991/2. Likewise for the Low Estimate consumption, we compute the annual equivalents over the periods 1979/80 - 2003/4 and 1979/80 - 1995/6 for the metering and pipeline projects respectively. The difference between the annual equivalents calculated as above will indicate whether metering is in fact a more economic proposition than the non-metering proposal.

The above method overcomes the legitimate objection of the MWB to the method employed by the HCC in its calculations where costs under the two schemes were discounted over a 20 year period with no regard given to the unequal lives of the projects being compared [4, p.2].

3.5 Inflation and the Discount Rate

When measuring future costs and benefits of a project, account must be taken of changes in price levels over time. This aspect of the analysis is especially relevant when a project which is, say labour-intensive is being compared with a capital-intensive project. Such in fact is the case in our study. For metering which involves mainly reading and billing costs after installation, the major component of future costs is that of labour. Building a new pipeline, on the other hand, requires large quantities of building materials and hence may be classified as a capital-intensive project.

Now if the prices of materials were to rise at the same rate as labour wage rates, there would be no need to incorporate inflation explicitly into the analysis. Simply estimating the future costs and benefits in terms of constant prices and discounting them by an inflation-free discount rate would yield the correct results. This in fact is the assumption frequently made by analysts to take care of the problem of inflation. However, to do so in our case would be distorting the situation in reality. A survey of price indexes for the past 10 years for various items that enter the 2 projects in question reveal that their rates of increase have not been identical [21, Table 1].

So as to reflect the relative rates of increase and not to bias against either project, it would be ideal to escalate all future costs and benefits by the appropriate rates. Discounting these back by an interest rate which incorporates the expected change in the general price level would then give the desired results [46, p.8]. This method however requires accurate forecasts of the various rates of increase in prices. A similar method which yields identical results to the latter involves the use of constant prices for all the cost categories but adjusted for any relative difference in the rates of increase. Thus if we know from past trends the relative differences in the rates of increase in prices ~~inflation~~ for different items, we can incorporate it into the analysis by maintaining one of the cost items at constant prices (zero inflation rate) and adjusting all other future cost estimates for the relative margins. The appropriate discount rate to use would then be the inflation-free discount rate.

In our study there are three principal items whose prices have increased in the past at different rates. They are materials used in the construction of pipelines and meters, labour, and electricity to work the water pumps. By our method, we maintain the rate of price increase in materials at zero and adjust the future constant price estimates of labour and electricity charges upwards by 2% and downwards by 2% respectively. By doing this we are effectively assuming that in future labour wage levels will rise at a rate 2% above the rate of increase in material prices and the industrial price of electricity will increase at a rate 2% below it. This relative difference in the rates was obtained by inspecting the past trends in the following 3 indexes:

(i) Wholesale Price Index of Materials Used in Building other than House Building. (Steel and Iron Products). Source: Tasmanian Year Book (various issues).

(ii) Weighted Average Minimum Weekly Wage Rates and Index Numbers (31st Dec.). Adult Males (Public Authority (n.e.i.) and community and business services). Source: Tasmanian Year Book (various issues).

(iii) The Industrial Price of Electric Power in Tasmania.[13] Source: Tasmanian Year Book (various issues).

Our future cost and benefit estimates were therefore adjusted as follows:-

(a) Maintained at constant (77/8) prices (i.e. zero inflation rate):

C1: Purchase and installation of meters

B1: Non-installation of new pipeline

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13. This index was also used to convert the price of excess water in the North in each year of the sample period to real terms (1966/7 prices) for the purpose of estimating the excess demand function, assuming excess water charges in the past were based on operating costs, the main component of which is electricity to work the pumps.

(b) Constant (1977/8) prices adjusted at a positive rate of 2%:

C2: Reading, Billing and Maintenance of meters.

B2: Non-imposition of restrictions before completion of new pipeline.

(c) Constant (1977/8) prices adjusted at a negative rate of 2%:

C3: Loss of Consumers' surplus (assuming a marginal cost pricing policy is adopted for excess water under metering).

C4: Operational Costs of producing excess water.

B3: Avoidance of operational costs of providing larger quantity of excess water.

Having estimated all future costs and benefits in terms of constant 1977/8) prices, it is necessary to discount them back to the base year (in our case 1978/9) so that the benefits and costs of the project may be aggregated. Because of our choice of method to deal with inflation, the discount rate chosen for this purpose must be one which does not include the rate of inflation. Ideally the discount rate should reflect the rate of time preference of society. According to Layard, "....the adjusted long term bond rate probably gives as good evidence as we are likely to get on (the) risk-free time preference." [30, p.35]. However, instead of adjusting the current long-term bond rate for expected inflation, we have chosen to use the average interest rate on long term bonds in the mid-1930's, assuming it gives a fairly accurate reflection of the true time preference rate in Australia. This was found to be about 3% p.a. The discount rate used in our analysis was thus 3%. For the purpose of sensitivity analysis the rates of 2%, 4% and 5% were also used.

3.6 Sensitivity Analysis

In our study, it appears that a fairly crucial assumption made concerns the rate at which water consumption grows in the future, or the growth in the number of connections, since we are linking this to the latter. The rate of growth of the number of connections is critical in determining the time interval before the construction of the new pipeline becomes necessary and thus influences the magnitude of savings made possible through metering. It also affects cost items such as the purchase and installation of meters, reading and billing costs and the consumers' surplus foregone.

The number of properties that will be connected to water supplies over the next 10-25 years is by no means certain. Like population forecasts, a variety of estimates with a fairly wide spread exists [see 16, Appendix 3]. In the presence of such uncertainty, it is necessary to employ "sensitivity analysis"; by estimating the future benefits and costs with different rates of growth in the number of connections, it is possible to ascertain the extent to which the project outcome is sensitive to differences in this respect. For our purpose we have conducted the analysis with 2 sets of growth rates for each of the 4 councils in the Hobart area. The first set (referred to as the 'High Estimate') was based as the forecast figures for the "Number of Tenements" in the MWB Report on the new pipeline project [5, Appendix].

The alternative regime (known as the 'Low Estimate' assumption) follows a more conservative forecast of the growth rates. The rates chosen are designed to give an overall average figure which matches more closely the actual growth experienced by Hobart over the last 10 years (which was about 2.1% p.a.). The rates for the 4 councils under the two assumptions are as follows:

	High Estimate	Low Estimate
Hobart City Council	1.5%	1.1%
Glenorchy City Council	2.1%	1.5%
Clarence Council	2.6%	2.0%
Kingborough Council	6.9%	6.0%
Four councils' annual average:	2.6%	2.1%

Assuming that the rate of growth of the number of connections is influenced by the rate of population growth, then it is highly unlikely that the future growth rate in the number of connections will show a marked increase from the trend experienced in the recent past. An indication of this is the average population growth rate in Tasmania, which has been on the decline ever since the early 1950's and the trend is not expected to be reversed over the near future [see 1, p.56]. We therefore contend that the Low Estimate assumption is probably the more relevant one for decision making purposes.

CHAPTER 4

THE COSTS OF METERING

Having described the cost items associated with metering Hobart's water supplies in Chapter 2, we now proceed to quantify them. The excess-demand-for-water function formulated in Section 2.4 was necessary for estimating certain costs that follow. It was also required to determine when, under the metering proposal, the new pipeline would have to be built. In Section 4.1 therefore we present the estimated equation and explain how it was adopted to perform the Williamson analysis [52]. This is followed by the cost estimates of metering.

4.1 Demand for Excess Water in Hobart

The equation expressing the demand for excess water was estimated by OLS using annual data from the Substitute Area. A list of the data can be found in Appendix 3. Since our Substitute Area comprises 2 adjoining regions, the data for these areas was pooled for the regression. The results of the estimation are as follows:[14]

$$\underset{(2.975)}{Q = 790.698} \quad + \underset{(0.366)}{0.016C} \quad - \underset{(-0.761)}{40.558P} \quad - \underset{(-1.942)}{0.813R} \quad - \underset{(-1.882)}{262.217S}$$

where the variables are as defined on page 20.

$\bar{R}^2 = 0.35$ DW Statistic = 1.52 F-Test = 4.12

The t-ratios (shown in brackets below the coefficients) indicated that the constant, rainfall and restrictions were significant.[15] The generally low $\bar{R}^2$ and t-ratio values were due

14. The function was also estimated with Average Maximum Summer Temperature included among the variables. It was however inferior to the one presented.

15. Unless otherwise stated, all tests for significance were conducted at the 5% level.

likely to the high level of correlation between the number of connections variable and real price. This was confirmed when another regression, without those 2 variables, indicated improved values for $\bar{R}^2$ and the t-ratios of the remaining variables. For this reason, the number of connections and real-price were retained in the equation.[16] The Durbin-Watson statistic was in the inconclusive region[17] but inspection of the autocorrelation function confirmed the absence of autocorrelation.

The average rainfall in Hobart for the period October to February is 268mm [6]. Based on the rainfall figure for the same period in a moderately dry year (1973/4, 6% below average) we define a 'dry' summer to be one where rainfall over the Oct.-Feb. period is 10% below average, i.e. 241mm. Assuming that the MWB should plan future water supplies according to higher-than-average summer demand, the dry summer rainfall value was substituted into the estimated equation above to obtain the 'operational' excess-demand equation. As we are now using the equation for Hobart, the dummy variable S can be maintained throughout the period of analysis at 0.

The operational excess-demand equation thus becomes:

$$Q = 594.837 + 0.016\ C - 40.558\ P.$$

Thus for any particular year, the position of the excess demand curve can be determined by setting C at the appropriate value and plotting P against Q.

To complete the model outlined in Section 2.4, we need the short-run and long-run marginal cost values. These were calculated using the formulae on page 23. Forecasts of operating

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16. Also, because the underlying reasoning of the demand function indicates that these variables be included, their exclusion could possibly lead to misspecification error, the consequences of which are severe [32, p.16].

17. See Kmenta [30] for tests for autocorrelation.

costs and maintenance expenditure for the period 1983/4 - 1988/9 were obtained from the MWB report [5, Appendix].[18] The calculated SRMCs for each year in the period are shown in Table 1 (in 1977/8 prices).

TABLE 2: SHORT RUN MARGINAL COST OF PRODUCING WATER

Year	SRMC (¢/Kl)
1983/4	9.083
84/5	8.420
85/6	8.373
86/7	8.321
87/8	8.272
88/9	8.221

$$\text{Hence, } b = \frac{1}{6} \Sigma \frac{\Delta V_t}{\Delta Q_t}$$

= 8.45 ¢/Kl ('77/8 prices)

= 4.08 ¢/Kl ('66/7 prices)

The average capacity costs (β) of a fully utilized pipeline equal average annual maintenance cost plus $\frac{R}{Z}$, where R and Z are as defined on page 23. The average annual maintenance cost per unit of water produced was estimated by calculating the average "Administration & Engineering" costs found in the MWB report [5, Appendix] for the period 1982/3 - 1985/6 and extrapolating it to the year 1993/4 when it is assumed that the new pipeline will be operating either at or close to full capacity. This was found to be 2.75 ¢/Kl (in '77/8 prices). Calculation of R was based on the assumptions that the effective lifetime of the new pipeline is about 15 years (i.e. before additional capacity becomes necessary) and that the foregone alternative is a purchase of long-term

18. The figures in the report were lagged 1 year because of our assumption that work on the new pipeline will begin in 1979/80 and not 1978/9.

semi-governmental bonds with an annual yield of 9.5% (this figure was the average yield as at November 1978 for several local semi-governmental bodies, e.g. Telecoms,HEC).

Therefore $R = 30\ 300\ 000\ A^{-1}_{\overline{15}|\,0.095} = \$\ 3\ 870\ 634$

where \$30.3m is the estimated capital cost (1977/8 prices) of the new pipeline [5].

Hence $\frac{R}{Z} = \frac{3\ 870\ 634}{150\ 000 \times 365}$ (daily capacity of new pipeline = 150Ml).

$= 7.07$ ¢/Kl.

Consequently, $\beta = 2.75 + 7.07$

$= 9.82$ ¢/Kl ('77/8 prices)

$= 4.73$ ¢/Kl ('66/7 prices)

Hence, LRMC $= b + \beta$

$= (4.08 + 4.73)$

$= 8.81$ ¢/Kl ('66/7 prices).

The levels of excess-water consumption at which the present supply and the augmented supply reach full capacity (i.e. Q_1 and Q_1+E in Fig. 2) were found, using the operational equation, to be 1313.15 Ml and 1585.74 Ml respectively. Amount consumed at point J in Fig. 2 is therefore 1449.45 Ml. With the above data, simple manipulation of the operational equation showed that the excess demand curve will pass through the critical point J in either 1999/2000 (High Estimate) or 2004/5 (Low Estimate). Under metering therefore the new pipeline becomes necessary only in those years. The periods of analysis for the metering scheme under the 'High' and 'Low' assumptions are therefore 1979/80 - 1998/9 and 1979/80 - 2003/4 respectively.

4.2 The Cost of Purchasing and Installing Meters : C1

The cost of installing a meter in a Hobart household (including the price of the meter) was assumed to be \$61.86¢ ('77/8 prices).

This was in fact the cost experienced in the metered Substitute Area of our study. Assuming full metering will be achieved in 3 years, the costs to be incurred over the period of analysis under each of the two assumptions are shown in Appendixes 5A and 5B. It should be noted that we have only considered household meters in our study. We retain the MWB's assumption regarding industrial and high-usage commercial properties that they are "either already metered or will be charged an economic meter rent when installations are made". [3, p.7]. Figures are only shown for the 3% and 5% discount rates. Results for the 2% and 4% discount rates are included in the Appendix. We note also that since the average life of a meter is about 20 years [43, p.228; 8, p.13], mass replacement of meters would have to begin in the year 2000/1. Cost of these replacements is included under the Low Estimate Assumption.

The total discounted costs in this category are (in '77/8 prices):

	3%	5%
High Estimate	$3 931 149	3 594 100
Low Estimate	5 333 629	4 435 396

4.3 The Costs of Reading, Billing and Maintaining Meters: C2

The existing studies on metering in Hobart have all computed these costs by multiplying the number of meters in a particular year by an average cost per meter figure. This average cost figure covers such diverse costs as wages paid to employees and office rent. It is believed that in doing so, the studies have wrongly assumed that all costs in this category are variable, i.e. vary directly in proportion to the number of meters in existence. Clearly such expenses as office equipment and office rent will remain independent of the actual number of meters over a span of 25 years. We have therefore distinguished between the fixed costs (i.e. those costs which can be assumed to be independent of the actual number of meters) and variable costs.

The cost estimates were obtained by collating the information in the existing studies. We have assumed, as did the MWB in its submission [3] that meter reading, billing and maintenance work for all councils would be carried out from a centralized office. The fixed and variable costs are detailed below (in '77/8 prices):

A. FIXED COSTS		1979/80	Annually after '79/80
1. Labour		$	$
Meter Maintenance:	1 meter supervisor (50%)	6 000	6 000
	1 Leading-hand fitter	11 000	11 000
	1 Shop fitter	9 000	9 000
	1 Field fitter	9 000	9 000
	1 Tester	8 000	8 000
Meter Reading:	1 Supervisor (50%)	6 000	6 000
	Meter Readers (2 in 1979/80, 5 thereafter)	18 000	45 000
Customer Billing:	1 Clerk in charge	12 000	12 000
	2 Clerks	10 000	20 000
	1 Cashier	11 000	11 000
	1 Typist/Telephonist	7 500	7 500
20% Labour Overheads		23 500	28 900

(Cont...)

	1979/80	Annually After '79/80
2. Administrative	$	$
Telephone, Power, Light, Machine Maintenance etc.	4 000	4 000
Accommodation (Rent) @ $60 per square metre	7 200	7 200
Computing Cost (+ office equipment in 1979/80)	26 000	16 000
TOTAL FIXED COSTS:	168 200	200 600

B. VARIABLE COSTS

Transport	: 6¢	∴ total variable cost per meter = 71¢
Stationery	: 15¢	
Postage	: 20¢	
Maintenance materials	: 30¢	

The total discounted costs under this category are (in '77/8 dollars):

	3%	5%
High Estimate	$4 396 058	$3 616 899
Low Estimate	5 351 208	4 201 980

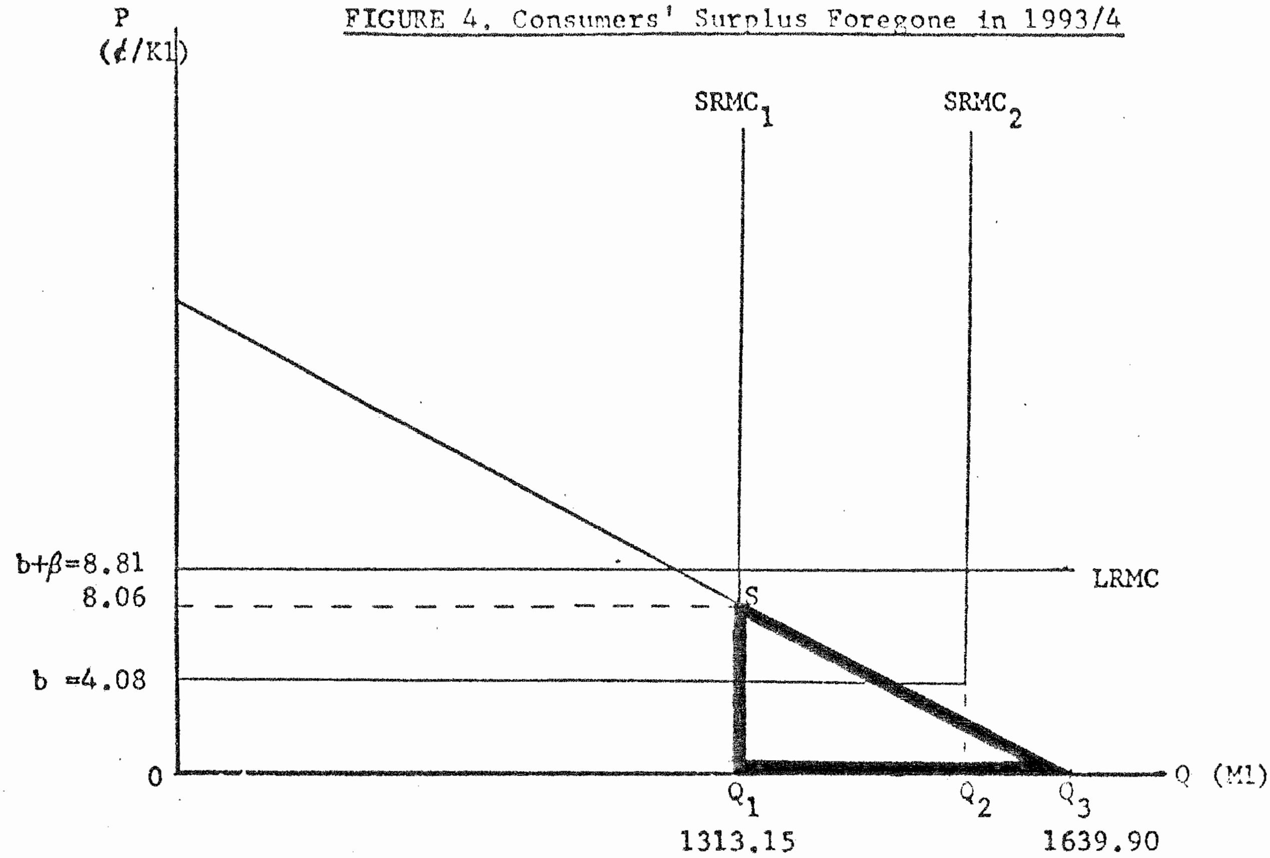
The annual figures are shown in Appendixes 6A and 6B.

4.4 The Cost of Consumers' Surplus Foregone: C3

The consumers' surplus for any given year is calculated by measuring the area under the excess-demand curve extending between the quantity levels demanded by consumers under metering and non-metering respectively. The meaning of this should be clear if we demonstrate the calculation of the loss in consumers' surplus for say 1993/4 under the 'High Estimate' assumption.

Fig. 4 shows the position of the excess demand curve in 1993/4. From the operational equation, we determine that a price of 8.06¢/Kl ('66/7 prices) must be charged in 1993/4 to keep demand down at present capacity level (i.e. Hobart will be on

FIGURE 4. Consumers' Surplus Foregone in 1993/4



point S on the excess demand curve). On the other hand if the non-metering proposal was continued, a total of 1639.9Ml of 'excess water' would have been consumed (assuming that capacity is expanded after 1991/2 when present supply meets demand at full capacity). The loss in consumers' surplus can thus be measured by the area enclosed in the figure Q_1SQ_3. This is given by:

$$\frac{1}{2} \times (OQ_3 - OQ_1) \times (SQ_1)$$

$$= \$[\tfrac{1}{2}\ (326\ 750)\ (0.0806)]$$

$$= \$13\ 168 \text{ ('66/7 prices)}$$

$$= \$27\ 310 \text{ ('77/8 prices).}$$

The total discounted values of the loss in consumers' surplus are (in '77/8 prices):

	3%	5%
High Estimate	\$185 325	\$142 703
Low Estimate	195 814	144 061

Annual figures are shown in Apendixes 7A and 7B.

4.5 The Operational Costs of Producing Excess Water: C4

If meters are installed, the operational costs of producing excess water should remain steady (in real terms) once consumption reaches present supply capacity (Q_1 in Fig. 4). The marginal cost of producing a kilolitre of water is 4.08¢; the real total cost of producing excess water under metering over the period when the present system is fully utilized is therefore

$(1 313 150 x 0.0408) = $53 577 ('66/7$)

=$111 118 ('77/8$)

Up to the year when the new pipeline will be needed under the metering proposal, the annual discounted operational costs are as shown in Appendixes 8A and 8B. We have assumed in our calculations of operational costs that all water supplied to consumers will be treated although it is realised that under present circumstances a fraction of the reticulated water is untreated (especially in summer when the demand places a strain on the available treatment works). This assumption is in line with the MWB's stated policy that it aims to treat all supplied water, as development of facilities proceeds [5, p.6].

The total discounted costs in this category are (in '77/8 prices):

	3%	5%
High Estimate	$1 303 931	$1 101 049
Low Estimate	1 464 826	1 201 107

CHAPTER 5

THE BENEFITS OF METERING

The benefits of introducing water metering to Hobart stem from the belief that a marginal cost pricing system will optimize the usage of water and defer or even avoid some of the expenses that would have to be incurred otherwise. In this chapter we quantify these benefits. Annual figures for B1 and B3 are shown in the Appendixes.

5.1 The Non-Installation of the New Pipeline: B1

We have assumed in our analysis that capital funds for either the metering or the pipeline project will not be forthcoming until 1979/80. The new pipeline programme, to be completed in 2 stages, could be spread over 10 years "to take into account the Board's capacity for raising loan funds". [5, p.8]. A copy of the table showing the construction and financial programme (in 1977/8 prices) if building work on the pipeline begins in 1979/80 is given below. The first stage, taking about five years, would be sufficient to alleviate any acute shortage of supply.

TABLE 3

Construction and Financial Programme for New Pipeline

(figures in $m) (Source: [5,p.10])

	1979/80	80/1	81/2	82/3	83/4	84/5	85/6	86/7	87/8	88/9
Head Works Bryn Estyn				1.0	0.7					
Treatment Works						1.0	1.0			
Pipeline to Glenorchy	3.0	3.0	3.8	3.5	3.0					
Booster Pump Elwick					0.3					
Pipelines:										
a) Clarence						1.0	0.6			
b) Lower Res. Glenorchy							0.8			
c) Domain								3.0	1.8	
d) Lower Res. Hobart									1.2	1.6
TOTAL:	3.0	3.0	3.8	4.5	4.0	2.0	2.4	3.0	3.0	1.6

The discounted values of the capital costs above are as follows:

	3%	5%
High Estimate	$27 292 722	$24 701 244
Low Estimate	27 192 722	24 701 244

These costs, because they would not be incurred if the metering proposal is accepted, therefore constitute a benefit of metering.

5.2 The Non-Imposition of Restrictions Prior to Completion of New Pipeline: B2

As was mentioned in the last Chapter, a five year installation lag exists before the first stage of the new pipeline becomes operational. The metering project on the other hand has an installation lag of about 3 years. Thus, Hobart would have to experience water restrictions for two more years than would be necessary under metering.

The cost of imposing water restrictions comprise mainly the wages paid to inspectors employed during the period of restrictions. As far as consumers' surplus is concerned, there would be no loss as a result of restrictions. This is because 'restrictions' (perhaps a misnomer) are designed to ensure that demand does not exceed supply, causing an uneven flow of water to consumers at the expense of connections situated on higher elevations. Thus, even without restrictions, the total quantity of water demanded by all consumers would still be the same (i.e. present capacity level). What costs restrictions do perhaps impose on consumers, while they are in force, and which can be avoided by metering are the inconvenience or the health dangers mentioned in Chapter 1 of this study (page 9). However, for the purpose of our study these costs were deemed non-quantifiable. It is argued that the exclusion of these costs from the analysis does not constitute a serious error because of the short space of time any particular zone in Hobart will be under restrictions each day. Furthermore consumers could minimize these effects of restrictions by 'stocking-up' water in their premises while restrictions are relaxed.

The MWB estimates that about seven inspectors would have to be employed at a total cost of $21 000 each year. The total benefits of restrictions not imposed under metering in the years 1982/3 and 1983/4 are:

		High/Low Estimate		
		1982/3	1983/4	Total
Constant benefits	(1977/8 prices)	$21 000	$21 000	
Adjusted benefits	(+2%)	23 186	23 649	
Discounted benefits:	3%	20 601	20 400	$41 001
(Base: 1978/9)	5%	19 075	18 530	$37 605

5.3 Avoidance of Operational Costs with New Pipeline: B3

Following the method used to compute the operational costs of producing excess water under the metering scheme, the operational costs that would have been incurred with the pipeline project (and hence saved through metering) were calculated. These costs extend over the period 1979/80 - 1991/2 under the High Estimate assumption and over the period 1979/80 - 1995/6 under the Low Estimate Assumption.

Thus for example in 1990/1, under the High Estimate assumption, the operational equation tells us that with a marginal price of zero for excess water, a total of [594.8374 + 0.0161 (59957)] = 1 560 150 Kl of excess water will be consumed.[19] Now, the marginal operating cost per kilolitre of water produced is 8.46 ¢/Kl ('77/8 prices). Thus the operational cost saved in 1990/1 under the

19. According to the High Estimate, there will be a total of 59,957 connections in Hobart in 1990/1; i.e. C = 59957.

metering proposal will be $(1 560 150 x 0.0846) = $131 989

The total discounted savings made in this category under metering are thus (in '77/8 prices).

	3%	5%
High Estimate	$1 096 030	$ 967 652
Low Estimate	1 318 074	1 131 850

CHAPTER 6

SUMMARY AND CONCLUSIONS

We recall from Chapter 1 the objectives of this study:

(i) to examine the present approach to investment decisions of the water supply authority in Hobart,

(ii) to evaluate the comparative efficiency of a marginal cost pricing system vis-a-vis the 'requirements' approach, and

(iii) to assess the economic feasibility of introducing a payment-for-use system in Hobart through the means of metering water supplies.

With regard to (i), we argued that the requirements approach to planning future water supplies together with the fixed rating system used by Hobart has severe limitations. It invariably leads to wasteful consumption of an economic good (water) and could readily lead to the construction of needlessly large water supply systems. It also disregards the price variable as a factor determining the quantity of water demanded. Implicit in the decision to expand capacity is the assumption that the benefit derived by the community from the new capacity will always exceed the costs of the extra capacity [19, p.1]. In the present economic context therefore, where capital funds have to be rationed among alternative uses, the requirements approach can best be described as obsolete.

To achieve a more efficient allocation of the State's resources (assuming it is a desirable objective), it is necessary that the supply of water be governed by some opportunity cost principles. A marginal cost pricing system for water would provide a firm set of criteria that reflects the social opportunity cost of supplying water. These criteria, coupled with a Social Welfare function (such as the one incorporated in Williamson's model) would ensure that investment in supply expansion does not occur prematurely. Therefore with regard to the second objective above, we contend that the

TABLE 4

Results of Cost-Benefit Analysis (base 1978/9)

Benefits/Costs	High Estimate ($)	Low Estimate ($)
(a) For the 3% rate of discount		
Costs: C1 -meter installation	3 931 149	5 333 629
C2 -meter running costs	4 396 058	5 351 208
C3 -consumers' surplus	185 325	195 814
C4 -operational costs	1 303 931	1 464 826
	9 816 463	12 345 477
Annual Equivalent:	636 814	690 581
Benefits: B1 -pipeline deferred	27 192 722	27 192 722
B2 -restrictions avoided	41 001	41 001
B3 -operational (negative) costs	1 096 030	1 318 074
	28 329 753	28 551 797
Annual Equivalent:	2 507 920	2 075 973
(b) For the 5% rate of discount		
Costs: C1 -meter installation	3 594 100	4 435 396
C2 -meter running costs	3 616 899	4 201 980
C3 -consumers' surplus	142 703	144 061
C4 -operational costs	1 101 049	1 201 107
	8 454 751	9 982 544
Annual Equivalent:	659 437	694 426
Benefits: B1 -pipeline deferred	24 701 244	24 701 244
B2 -restrictions avoided costs	37 605	37 605
B3 -operational (negative) costs	967 652	1 131 850
	25 706 501	25 870 699
Annual Equivalent:	2 596 974	2 213 135

price variable, if made use of according to marginal cost pricing rules, is superior to the requirements approach.

To assess whether or not a payment-for-use system is an economic proposition (objective (iii) above), we utilised the cost-benefit tool. Results of the cost-benefit analysis are presented in Table 4. Comparison of the annual equivalents under both the High and Low Estimates indicates that the benefits of metering exceed the costs by a very clear margin. (Results for the 2% and 4% discount rates are similar; see Appendix 9). We therefore conclude that metering Hobart's water supplies and implementing a marginal cost pricing policy are in fact more beneficial than building a new pipeline under the present flat-rate method of charging.

The importance of having an optimal pricing policy for the efficient management of demand cannot be over-emphasized.

> "While universal metering is a prerequisite to the introduction of an effective water price policy, the installation of meters *per se* does not guarantee an efficient use of water. This goes to say that if a water authority seeks a successful water control policy it should look to metering of water supplies <u>coupled with an effective water price policy</u>." [19, p.78, emphasis added].

It is plausible to have a metered situation which in fact creates a disincentive for the efficient use of water. This is true, for example, if the basic allowance given per household is so large that consumers are actually encouraged to use at least a 'minimum' quantity of water.

The analysis in this study is however not without its limitations. It must be borne in mind that the dependability of the results ultimately rests on the assumptions underlying the analysis. Our assumption that there would be no significant difference between the demand behaviour of consumers in the Substitute Area and Hobart under a pricing scheme is but a hypothesis that cannot be proven *a priori*. Based on geographical and climatic factors at least, the assumption seems reasonable. We have not included in our analysis the 'political cost' of implementing a pricing policy for water in Hobart. Obviously to introduce any sort of rationing system would be an unpopular proposition in the eyes of the public and metering is no exception. The political factor is an extremely subjective one and hence extremely difficult to accurately quantify. We believe however that metering could be made less objectionable to the public through proper education. The public needs to be made aware that water can no longer be regarded as a 'free good' and that its supply has to be governed by principles which also apply to other essentials, like electricity. In this way the 'political cost' attached to the metering alternative could be minimized or even avoided.

As of November 1978, it appears that with the States' successful procurement of the right to make overseas' loans, the government is bent on proceeding with the pipeline project. It may perhaps be too late to change that decision but it is hoped that the present study will serve to indicate the type of analysis that could assist in making the optimal decision when faced with a similar situation in future.

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APPENDIX 1

CONSUMPTION PER CONNECTION - LITRES PER DAY (ANNUAL AVERAGE)

	1970/1	'71/2	'72/73	'73/4	'74/5	'75/6
Hobart Metropolitan Area	695	735	863	819	820	793
West Tamar	498	484	591	535	525	535
North Esk (All Municipalities)	410	390	405	318	336	395

Source: [7]

APPENDIX 2

B1: CAPITAL COST OF THE NEW PIPELINE SAVED (High/Low Estimates)

(All figures in 1977/8 Dollars)

Year	Constant	Discounted at 2%	3%	4%	5%
1979/80	3 000 000	2 941 176	2 912 621	2 884 615	2 857 140
80/1	3 000 000	2 883 506	2 827 787	2 773 669	2 721 090
81/2	3 800 000	3 580 825	3 477 538	3 378 186	3 282 592
82/3	4 500 000	4 157 304	3 998 192	3 846 619	3 702 150
83/4	4 000 000	3 622 923	3 450 435	3 287 708	3 134 120
84/5	2 000 000	1 775 934	1 674 969	1 580 629	1 492 440
85/6	2 400 000	2 089 344	1 951 420	1 823 803	1 705 632
86/7	3 000 000	2 560 471	2 368 228	2 192 071	2 030 520
87/8	3 000 000	2 510 266	2 299 250	2 107 760	1 933 830
88/9	3 000 000	2 461 045	2 232 282	2 026 693	1 841 730
	TOTALS:	$28 582 794	27 192 722	25 901 753	24 701 244

APPENDIX 3

DATA USED IN THE ESTIMATION OF EXCESS-WATER DEMAND FUNCTION

	Year	Qty. (Ml)	Real Price (¢/Kl)	Connections	Rainfall (mm)	Restrictions
West Tamar:	1968/9	152.278 0	4.211	2 980	483	0
	69/70	306.906 6	4.147	3 066	251	0
	70/1	283.159 8	4.029	3 178	313	0
	71/2	253.162 1	3.780	3 371	471	0
	72/3	675.955 2	3.658	3 712	218	0
	73/4	481.449 8	3.429	3 818	364	0
	74/5	450.915 0	4.021	3 921	296	0
	75/6	503.875 0	4.681	4 031	355	0
	76/7	320.956 4	4.711	4 222	307	0
	77/8	650.850 0	6.375	4 339	258	0
North Esk:	1964/5	92.103 0	5.635	5 582	156	1
	65/6	359.430 5	5.578	5 941	131	0
	66/7	743.605 5	5.500	6 171	154	0
	67/8	508.287 5	5.345	6 475	171	0
	68/9	188.841 0	5.263	6 626	393	1
	69/70	542.655 0	5.184	7 002	223	1
	70/1	336.753 0	5.037	7 242	303	1
	71/2	202.751 5	4.725	7 651	370	1
	72/3	328.472 5	5.486	7 915	147	1
	73/4	0	5.456	8 276	275	1
	74/5	0	6.032	8 561	271	1
	75/6	307.510 0	7.022	8 786	264	1
	76/7	158.831 0	7 495	9 343	297	1
	77/8	39.148 0	8.000	9 787	209	1

APPENDIX 4A

B3: THE OPERATIONAL COSTS OF PRODUCING EXCESS-WATER WITH NEW PIPELINE SAVED (HIGH ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9.

	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	111 118	106 803	104 709	103 692	102 695	101 717
80/1	111 118	104 709	100 643	98 699	96 810	94 974
81/2	111 118	102 656	96 735	83 945	91 261	88 678
82/3	111 118	100 643	92 979	89 420	86 030	82 799
83/4	111 118	98 669	89 367	85 113	81 099	77 310
84/5	120 518	104 918	93 164	87 867	82 918	78 292
85/6	122 273	104 359	90 851	84 853	79 304	74 166
86/7	124 088	103 832	88 620	81 966	75 869	70 278
87/8	125 965	103 335	86 467	79 198	72 602	66 611
88/9	127 866	102 838	84 363	76 521	69 473	63 133
89/90	129 879	102 408	82 363	73 982	66 522	59 876
90/1	131 989	102 015	80 438	71 551	63 719	55 907
91/2	134 133	101 657	78 584	69 223	61 052	53 911
		TOTALS:	$1 169 283	1 096 030	1 029 354	967 652

APPENDIX 4B

B3: THE OPERATIONAL COSTS OF PRODUCING EXCESS-WATER WITH NEW PIPELINE SAVED (LOW ESTIMATE)

All Figures in 1977/8 dollars. Base Year for Discounting: 1978/9

	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	111 092	106 778	104 684	103 668	102 671	101 693
80/1	111 092	104 684	100 619	98 674	96 786	94 951
81/2	111 092	102 632	96 712	93 922	91 239	88 657
82/3	111 092	100 619	92 956	89 398	86 010	82 780
83/4	111 092	98 646	89 347	85 093	81 080	77 292
84/5	118 033	102 755	91 243	86 055	81 209	76 677
85/6	119 361	101 873	88 687	82 832	77 415	72 399
86/7	120 729	101 021	86 220	79 747	73 815	68 375
87/8	122 136	100 194	83 838	76 790	70 395	64 586
88/9	123 588	99 397	81 540	73 960	67 149	61 021
89/90	125 083	98 627	79 322	71 250	64 066	57 665
90/1	126 623	97 883	77 180	68 653	61 137	54 505
91/2	128 215	97 172	75 117	66 169	58 359	51 532
92/3	129 854	96 483	73 122	63 786	55 717	48 730
93/4	131 548	95 826	71 200	61 507	53 209	46 094
94/5	133 299	95 197	69 346	59 324	50 826	43 611
95/6	135 137	94 618	67 573	57 246	48 574	41 282
		TOTALS: $	1 428 706	1 318 074	1 219 657	1 131 850

APPENDIX 5A

Purchase and Installation Costs

(All figures in 1977/8 Dollars)

Year	No. of Meters Installed		Discounted Annual Costs (Base '78/9)			
	High Estimate	Low Estimate	High Estimate 3% ($)	High Estimate 5% ($)	Low Estimate 3% ($)	Low Estimate 5% ($)
1979/80	16 000	16 000	960 932	942 628	460 932	942 628
80/1	16 000	16 000	932 944	897 742	932 944	897 742
81/2	15 904	14 944	900 336	849 864	845 987	798 563
82/31	1 130	897	62 107	57 508	49 300	45 650
83/4	1 203	922	64 194	58 309	49 199	44 688
84/5	1 245	948	64 500	57 471	49 112	43 760
85/6	1 288	975	64 784	56 624	49 041	42 864
86/7	1 332	1 005	65 046	55 770	44 077	42 078
87/8	1 378	1 033	65 332	54 948	48 975	41 191
88/9	1 430	1 066	65 823	54 306	49 068	40 483
89/90	1 479	1 097	66 095	53 493	49 023	39 676
90/1	1 534	1 131	66 556	52 840	49 071	38 959
91/2	1 590	1 169	66 976	52 161	49 242	38 350
92/3	1 651	1 203	67 521	51 583	49 199	37 586
93/4	1 713	1 244	68 016	50 972	49 394	37 016
94/5	2 320	1 285	89 343	65 746	49 535	36 415
95/6	1 308	1 327	48 959	35 302	49 665	35 815
96/7	1 922	1 372	69 838	49 403	49 854	35 266
97/8	1 999	1 418	70 520	48 935	50 024	34 713
98/9	2 080	1 466	71 241	48 494	50 211	34 179
99/2000		1 519			50 511	33 728
2000/1		1 573			567 334	371 613
2001/2		1 629			552 565	355 045
2002/3		1 689			506 161	319 034
2003/4		1 750			78 205	48 354
TOTAL:			$3 931 149	3 594 100	5 333 629	4 435 396

APPENDIX 5B

C1: PURCHASE AND INSTALLATION COST OF METERS

All Figures in 1977/8 dollars. Base Year for Discounting: 1978/9

Year	High Estimate Discounted 2%	4%	Low Estimate 2%	4%
1979/80	970 353	951 692	970 353	951 692
80/1	951 326	915 089	951 326	915 089
81/2	927 077	874 613	871 117	821 820
82/3	64 579	59 753	60 062	47 431
83/4	67 403	61 166	51 658	46 879
84/5	68 388	60 867	52 073	46 346
85/6	69 363	60 547	52 507	45 834
86/7	70 326	60 207	53 061	45 426
87/8	71 328	59 891	53 469	44 896
88/9	72 568	59 760	54 096	44 549
89/90	73 583	59 431	54 577	44 081
90/1	74 822	59 270	55 166	43 699
91/2	76 033	59 071	55 901	43 430
92/3	77 403	58 978	56 400	42 975
93/4	78 734	58 839	57 178	42 730
94/5	104 543	76 623	57 904	42 440
95/6	57 785	41 539	58 624	42 142
96/7	83 245	58 690	59 424	41 895
97/8	84 883	58 693	60 212	41 634
98/9	86 591	58 723	61 030	41 388
99/2000			61 996	41 235
2000/1			703 157	458 698
01/2			691 566	442 462
02/3			639 700	401 407
03/4			99 806	61 423
TOTALS: $	3 946 499	3 604 329	5 942 363	4 841 601

APPENDIX 6A

C2: READING, BILLING AND MAINTENANCE COSTS (HIGH ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9.

Year	Constant	Adjusted 2%	Discounted 2%	3%	4%	5%
1979/80	179 560	186 814	183 151	181 373	179 629	177 918
80/1	223 320	236 989	227 786	223 385	219 110	214 956
81/2	234 680	254 025	239 373	232 469	225 827	219 437
82/3	235 438	259 943	240 147	230 956	222 200	213 855
83/4	236 292	266 103	241 018	229 543	218 717	208 500
84/5	237 172	272 441	241 920	228 165	215 314	203 301
85/6	238 091	278 962	242 853	226 822	211 988	198 253
86/7	239 037	285 671	243 817	225 511	208 737	193 354
87/8	240 015	292 577	244 815	224 236	205 561	188 598
88/9	241 030	299 691	245 851	222 998	202 461	183 983
89/90	242 080	307 016	246 922	221 795	199 432	179 506
90/1	243 169	314 565	248 032	220 630	196 476	175 162
91/2	244 298	322 346	249 184	219 502	193 593	170 947
92/3	245 471	330 372	350 381	218 415	190 782	166 861
93/4	246 687	338 648	251 620	217 365	188 039	162 896
94/5	248 334	347 728	253 301	216 693	185 655	159 298
95/6	249 263	356 009	254 248	215 391	182 765	155 327
96/7	250 627	365 116	255 639	214 467	180 232	151 713
97/8	252 047	374 529	257 088	213 589	177 767	148 212
98/9	253 523	384 256	258 593	212 753	175 369	144 822
		TOTALS: $	4 875 739	4 396 058	3 979 654	3 616 899

APPENDIX 6B

C2: READING, BILLING AND MAINTENANCE COSTS (LOW ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9

Year	Constant	Adjusted 2%	Discounted 2%	3%	4%	5%
1979/80	179 560	186 814	183 151	181 372	179 629	161 377
80/1	223 320	236 989	227 786	223 384	219 110	214 956
81/2	211 210	228 620	215 433	209 219	203 242	197 491
82/3	234 567	258 981	239 258	230 100	221 378	213 064
83/4	235 222	264 898	239 926	228 502	217 727	207 555
84/5	235 895	270 970	240 614	226 932	214 152	202 202
85/6	236 587	277 200	241 319	225 388	210 649	197 001
86/7	237 301	283 596	242 046	223 872	207 221	191 949
87/8	238 034	290 161	242 794	222 383	203 863	187 040
88/9	238 791	296 906	243 566	220 925	200 579	182 275
89/90	239 570	303 832	244 361	219 494	197 363	177 644
90/1	240 373	310 949	245 181	218 093	194 218	173 148
91/2	241 203	318 263	246 028	216 721	191 141	168 782
92/3	242 057	325 777	246 898	215 376	188 128	164 540
93/4	242 940	333 506	247 800	214 064	185 184	160 422
94/5	243 852	341 451	248 729	212 780	182 303	156 423
95/6	244 795	349 628	249 691	211 532	179 490	152 542
96/7	245 769	358 039	250 684	210 311	176 738	148 773
97/8	246 776	366 697	251 712	209 123	174 050	145 114
98/9	247 816	375 607	252 773	207 966	171 422	141 562
99/2000	248 895	384 787	253 873	206 843	168 857	138 116
2000/1	250 012	394 244	255 012	205 754	166 355	134 772
01/2	251 168	403 989	256 192	204 699	163 911	131 527
02/3	252 368	414 037	257 416	203 680	161 526	128 380
03/4	253 610	424 396	258 682	202 695	159 200	125 325
		$	6 080 925	5 351 208	4 548 436	4 201 980

APPENDIX 7A

C3: LOSS OF CONSUMERS' SURPLUS (HIGH ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9

Year	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	2 427	2 333	2 287	2 265	2 243	2 222
80/1	4 577	4 313	4 146	4 065	3 988	3 912
81/2	6 286	5 807	5 472	5 314	5 162	5 016
82/3	5 683	5 147	4 755	4 573	4 400	4 234
83/4	4 862	4 335	3 926	3 739	3 563	3 397
84/5	7 002	6 096	5 413	5 105	4 818	4 549
85/6	7 002	5 976	5 202	4 859	4 541	4 247
86/7	7 002	5 859	5 001	4 625	4 281	3 966
87/8	7 856	6 445	5 393	4 940	4 528	4 155
88/9	10 061	8 092	6 638	6 021	5 467	4 968
89/90	12 620	9 951	8 003	7 189	6 464	5 818
90/1	15 580	12 044	9 497	8 447	7 523	6 707
91/2	18 977	14 382	11 118	9 793	8 637	7 627
92/3	22 885	17 004	12 887	11 242	9 819	8 588
93/4	27 310	19 887	14 776	12 765	11 042	9 566
94/5	33 898	24 209	17 635	15 086	12 925	11 090
95/6	37 929	26 556	18 965	16 067	13 633	11 586
96/7	44 272	30 390	21 278	17 851	15 001	12 628
97/8	51 369	34 570	23 730	19 715	16 408	13 680
98/9	59 304	39 127	26 331	21 644	17 857	14 747
		TOTALS: $	212 453	185 325	162 300	142 703

APPENDIX 7B

C3: LOSS OF CONSUMERS' SURPLUS (LOW ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9

Year	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	2 462	2 366	2 320	2 297	2 275	2 253
80/1	4 733	4 460	4 287	4 203	4 124	4 045
81/2	6 570	6 070	5 720	5 555	5 396	5 243
82/3	6 216	5 630	5 201	5 002	4 813	4 632
83/4	7 000	6 216	5 630	5 362	5 109	4 870
84/5	7 000	6 094	5 411	5 104	4 816	4 547
85/6	7 000	5 974	5 201	4 857	4 540	4 246
86/7	7 000	5 857	4 999	4 624	4 280	3 964
87/8	7 000	5 742	4 805	4 401	4 034	3 701
88/9	7 000	5 630	4 619	4 189	3 803	3 456
89/90	7 282	5 742	4 618	4 148	3 730	3 357
90/1	8 941	6 912	5 450	4 848	4 317	3 849
91/2	10 473	7 937	6 136	5 405	4 767	4 209
92/3	12 863	9 557	7 243	6 318	5 519	4 827
93/4	14 948	10 889	8 091	6 989	6 046	5 238
94/5	17 638	12 596	9 176	7 849	6 725	5 770
95/6	20 605	14 427	10 303	8 729	7 406	6 294
96/7	23 932	16 428	11 502	9 650	8 109	6 826
97/8	27 637	18 599	12 767	10 607	8 828	7 360
98/9	31 747	20 946	14 096	11 597	9 559	7 894
99/2000	36 307	23 485	15 495	12 624	10 306	8 430
2000/1	41 351	26 223	16 962	13 686	11 065	8 964
01/2	46 921	29 172	18 500	14 781	11 836	9 498
02/3	53 066	32 345	20 110	15 912	12 619	10 029
03/4	59 834	35 756	21 794	17 077	13 413	10 559
	TOTALS:	$	230 436	195 814	167 435	144 061

APPENDIX 8A

C4: OPERATIONAL COSTS OF PRODUCING EXCESS-WATER (HIGH ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9

Year	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	98 563	94 738	92 880	91 978	91 094	90 227
80/1	100 056	94 285	90 624	88 873	87 172	85 519
81/2	101 595	93 859	88 445	85 894	83 441	81 079
82/3	103 181	93 454	88 064	83 033	79 884	76 885
83/4	104 820	93 077	84 303	80 289	76 503	72 929
84/5	106 516	92 729	82 341	77 659	73 285	69 196
85/6	108 271	92 408	80 447	75 136	70 223	65 673
86/7	110 086	92 116	78 620	72 717	67 308	62 348
87/8	111 118	91 156	76 276	69 864	64 045	58 760
88/9	111 118	89 368	73 313	66 948	60 373	54 864
89/90	111 118	87 615	70 465	63 295	56 913	51 227
90/1	111 118	85 898	67 730	60 247	53 652	47 831
91/2	111 118	84 214	65 100	57 346	50 576	44 660
92/3	111 118	82 562	62 572	54 583	47 678	41 700
93/4	111 118	80 944	60 142	51 955	44 945	38 936
94/5	111 118	79 356	57 807	49 452	42 369	36 354
95/6	111 118	77 800	55 562	47 071	39 940	33 944
96/7	111 118	76 275	53 405	44 803	37 652	31 694
97/8	111 118	74 779	51 331	42 646	35 493	29 592
98/9	111 118	73 313	49 337	40 592	33 459	27 631
		TOTALS: $	1 428 764	1 303 931	1 196 005	1 101 049

APPENDIX 8B

C4: OPERATIONAL COSTS OF PRODUCING EXCESS-WATER (LOW ESTIMATE)

All Figures in 1977/8 Dollars. Base Year for Discounting: 1978/9

Year	Constant	Adjusted (-2%)	Discounted 2%	3%	4%	5%
1979/80	97 919	94 117	92 271	91 375	90 497	89 635
80/1	99 077	93 362	89 736	88 002	86 318	84 682
81/2	100 265	92 630	87 287	84 769	82 348	80 017
82/3	101 486	91 919	84 919	81 669	78 573	75 622
83/4	102 742	91 232	82 631	78 697	74 986	71 483
84/5	104 033	90 567	80 421	75 848	71 576	67 582
85/6	105 361	89 925	78 285	73 117	68 336	63 908
86/7	106 730	89 307	76 223	70 499	65 256	60 446
87/8	108 137	88 710	74 229	67 989	62 326	57 183
88/9	109 589	88 138	72 304	65 583	59 543	54 109
89/90	111 092	87 595	70 449	63 280	56 900	51 215
90/1	111 092	85 877	67 713	60 232	53 639	47 820
91/2	111 092	84 194	65 085	57 332	50 565	44 650
92/3	111 092	82 542	62 557	54 570	47 666	41 689
93/4	111 092	80 925	60 128	51 942	44 935	38 926
94/5	111 092	79 337	57 793	49 440	42 359	39 345
95/6	111 092	77 782	55 549	47 060	39 931	33 936
96/7	111 092	76 257	53 392	44 793	37 643	31 686
97/8	111 092	74 762	51 319	42 636	35 485	29 586
98/9	111 092	73 296	49 326	40 582	33 451	27 624
99/2000	111 092	71 859	47 411	38 628	31 534	25 793
2000/1	111 092	70 450	45 570	36 768	29 727	24 083
01/2	111 092	69 069	43 801	34 997	28 023	22 487
02/3	111 092	67 714	42 099	33 311	26 417	20 996
03/4	111 092	66 387	40 465	31 707	24 903	19 604
		TOTALS: $	1 630 963	1 464 826	1 322 937	1 201 107

APPENDIX 9

RESULTS OF COST-BENEFIT ANALYSIS (base 1978/9)

Benefits/Costs	High Estimate ($)	Low Estimate ($)
(a) For the 2% rate of discount		
Costs: C1 - meter installation	3 946 499	5 942 363
C2 - meter running costs	4 375 739	6 080 925
C3 - consumers' surplus	212 453	230 436
C4 - operational costs	1 428 764	1 630 963
	10 463 455	13 884 687
Annual Equivalent:	615 094	690 055
Benefits:		
B1 - pipeline deferred	28 582 794	28 582 794
B2 - restrictions avoided	42 840	42 840
B3 - operational (negative) costs	1 169 283	1 428 706
	29 794 917	30 054 340
Annual Equivalent:	2 461 120	2 004 685
(b) For the 4% rate of discount		
Costs: C1 - meter installation	3 604 329	4 841 601
C2 - meter running costs	3 979 654	4 548 436
C3 - consumers' surplus	162 300	167 435
C4 - operational costs	1 196 005	1 322 937
	8 942 288	10 880 409
Annual Equivalent	637 406	680 755
Benefits:		
B1 - pipeline deferred	25 901 753	25 901 753
B2 - restrictions avoided	39 257	39 257
B3 - operational (negative) costs	1 029 354	1 219 657
	26 970 364	27 160 667
Annual Equivalent:	2 553 257	2 145 503

10 B3 appears to be smaller than C4 because of the unequal project lifetimes.